11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

Direct Numerical Simulation of turbulent natural convection flow at high Rayleigh numbers in a realistic differentially heated cavity

L.Cadet[1], A.Sergent[2], S.Xin[3], D.Saury[4] and P.Joubert[1]

[1] LaSIE, Université de La Rochelle, F-17042 La Rochelle cedex, France
[2] LIMSI-CNRS, BP 133, F-91403 Orsay cedex, France
[3] CETHIL , INSA-Lyon, UMR5008, 20 Av., A. Einstein, F-69621 Villeurbanne Cedex, France
[4] PRIMME, ENSMA, BP 30179, F-86962 Futuroscope Chasseneuil cedex, France

Key Words: *Direct Numerical Simulation, Turbulent Natural Convection, Experimental Data*

Turbulent natural convection flows are present in many practical configurations, for example leaving or technical rooms, double-skin façade buildings… A better understanding of the involved flow is necessary to provide reference results and improve the accuracy of reduced models used in the design process or in the performance estimate of buildings or industrial processes.

Buoyancy-induced cavity flows have been widely investigated for the last decades due to the contrast between their apparent simplicity, reflected by the conservation of symmetries and the restricted domain size, and the complexity of the flow structure (thin transitional boundary, gravity waves, recirculation regions) or the involved physical mechanisms, which result from the strong coupling between the flow and the temperature field through the heat transfers. Particularly recent studies have demonstrated the major influence of radiative transfer on these flows [2],[3]. However, performing direct numerical simulations for typical Rayleigh numbers ($Ra \sim 10^{12}$) of the building industry remains strongly challenging [4],[5].

In this paper, we consider an experimental set-up located at the PPRIME Institute. It is an air-filled differentially heated cavity (3.81 m high, 1 m wide, 0.81 m deep), for which temperature and velocity databases are available at Ra equal to 4.10^{10} [1]. We present DNS results at Ra= 4.10^{10}. This DNS is based on a finite volume approach and overcomes the wall radiation heat transfer by using the temperature experimental measurements as Dirichlet boundary conditions at wall, following the methodology of [2]. DNS results and experimental database will be analyzed regarding the heat transfers at wall as well as their influence on velocity and turbulent fields. First our DNS approach will be validated at a slightly lower Ra by comparison with spectral DNS results obtained from a full convection-conduction-surface radiation coupling, approach previously developed by Xin & al. [3]. Both these DNS use HPC techniques as hybrid parallel computing (OpenMP/MPI) and domain decomposition techniques.

REFERENCES

[1] D. Saury, N. Rouger, F. Djanna, F. Penot, *Natural convection in an air-filled cavity: Experimental results at large Rayleigh numbers*, ICHMT, (38), 2011, 679-687.

[2] A. Sergent, P. Joubert, S. Xin, P. Le Quéré, *Resolving the stratification discrepancy of*

turbulent natural convection in differentially heated air-filled cavities Part II. End walls effects, Int. Journal Heat Fluid Flow, (39), 2013, 15-27.

[3]S. Xin, J. Salat,P. Joubert, A. Sergent, P. Le Quéré, F. Penot, *Resolving the stratification discrepancy of turbulent natural convection in differentially heated air-filled cavities Part III. A full convection-conduction-surface radiation coupling*, Int. Journal Heat Fluid Flow, (42), 2013, 33–48.

[4]X. Trias, A. Gorobets, M. Soria, A. Oliva, A., *Direct numerical simulation of a differentially heated cavity of aspect ratio 4 with Rayleigh numbers up to* 10^{11} *- part I: Numerical methods and time-averaged flow*. Int. J. Heat Mass Transfer 53, 665–673, 2010a.

[5]X. Trias, A. Gorobets, M. Soria, A. Oliva, *Direct numerical simulation of a differentially heated cavity of aspect ratio 4 with Rayleigh numbers up to 1011 - part II: heat transfer and flow dynamics*. Int. J. Heat Mass Transfer 53, 674–683, 2010b.